Southeast Puget Sound Groundwater Flow Model

Effects of pumping and drought on streamflow

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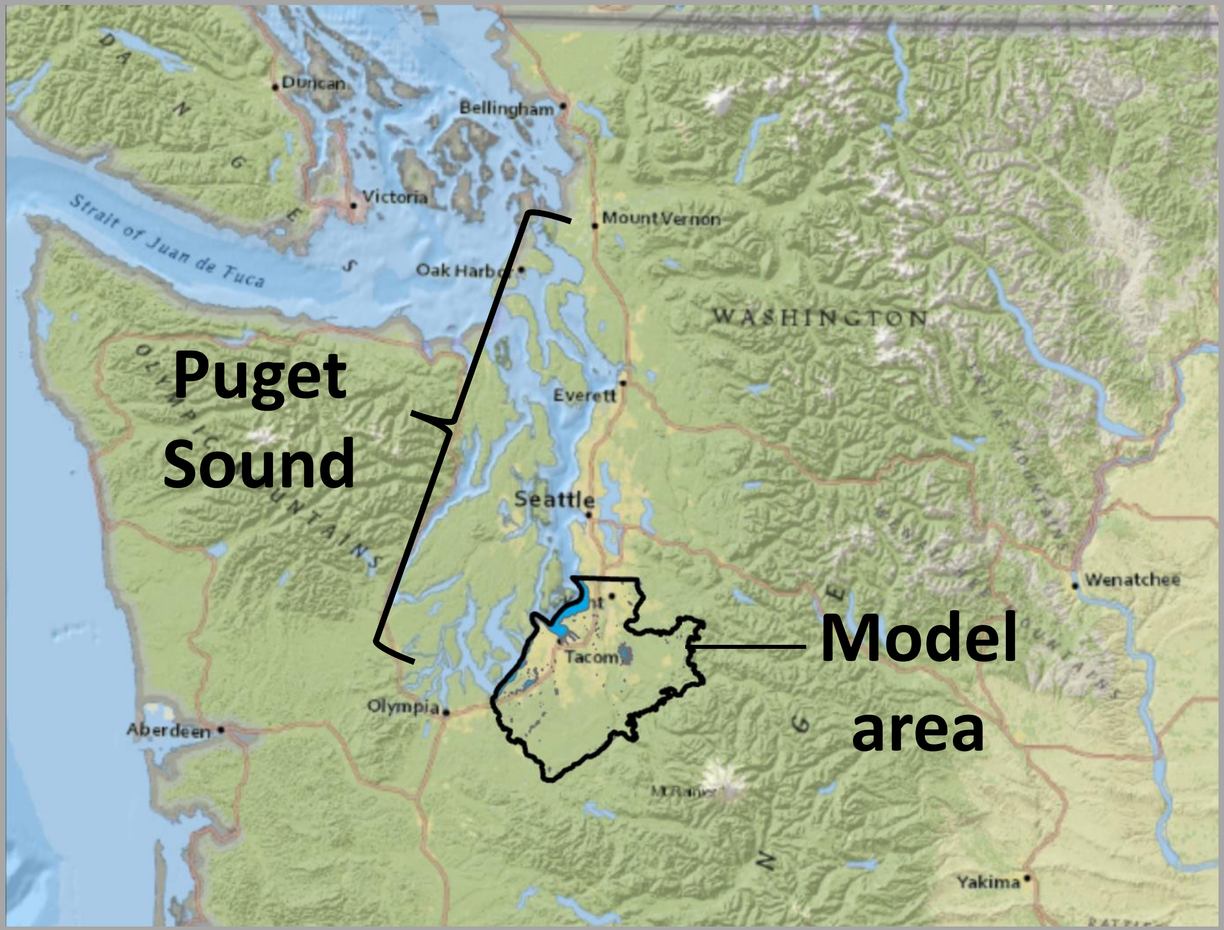
Joint Legislative Task Force on Water Resource Mitigation
May 24, 2022



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Presentation Outline

- USGS groundwater models in WA and Southeast Puget Sound (SES) project background
- Stratigraphic framework built into the model
- Overview of model construction and boundary conditions
- Generalized groundwater flow and budget—estimated and simulated
- Scenarios of pumping and drought
- Model limitations

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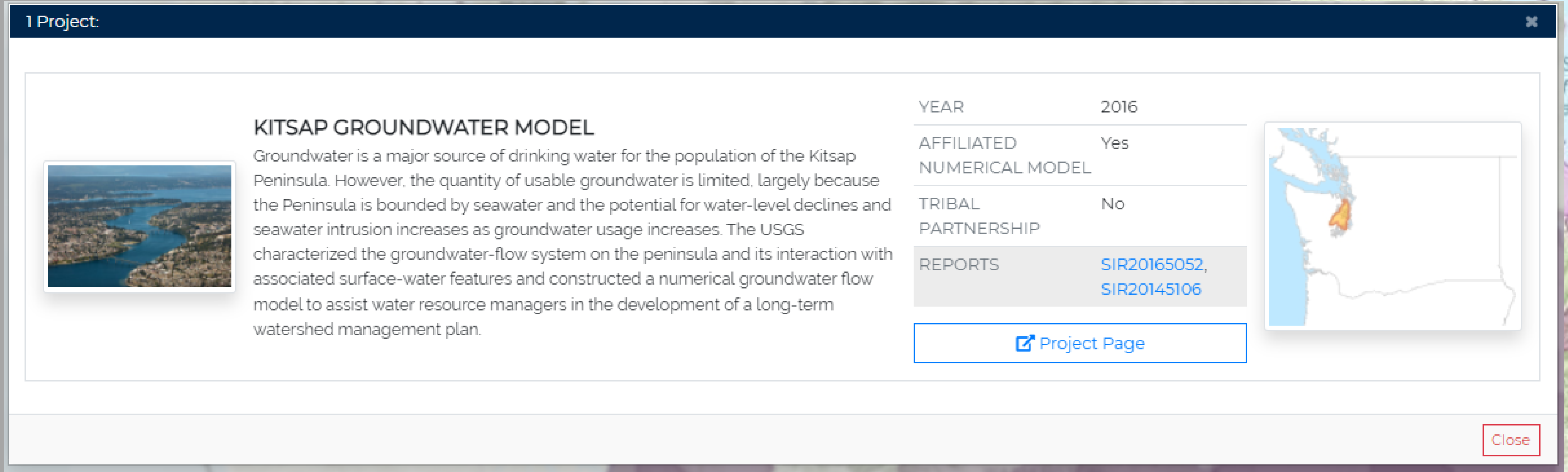
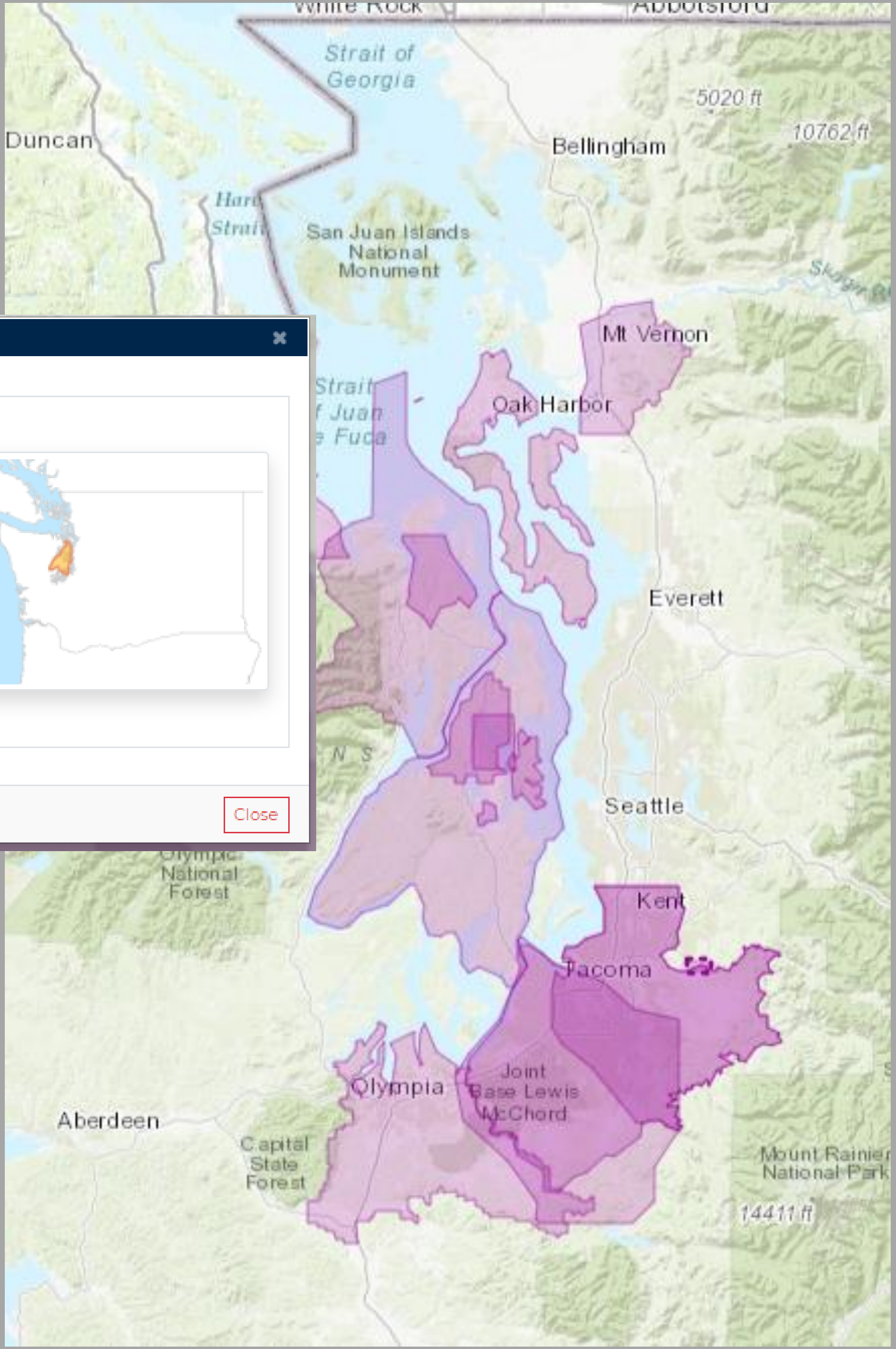
USGS Groundwater Models - Washington





- Web application showing USGS groundwater projects in Washington
- Selection shows projects with affiliated gw model
- https://webapps.usgs.gov/wawscgw/

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SES Project partners

- State and local government and private funding partners
- Provided data, technical support, and courtesy reviews
- Promotes long-term stewardship

City of Auburn Washington
City of Sumner Washington
City of Milton Incorporated 1907
City of Puyallup State of Washington
Washington State Department of Health
Pierce County Washington
Department of Ecology State of Washington
Tacoma Power Tacoma Water Tacoma Rail Tacoma Public Utilities
Tacoma - Pierce County Health Department Healthy People in Healthy Communities
Pierce Conservation District Conservation Across Pierce County
Public Utility District No. 1 of Thurston County
Cascade Water Alliance
Parkland Light & Water 1914 ~ 100 Years of Service ~ 2014
Firgrove Mutual Water Company
Lakehaven Water & Sewer District Providing water and sewer services to communities in South King County.
Summit Water & Supply Co 9701 50th Ave. East • Tacoma, WA 98446-5444 Phone: (253) 537-7781 • Fax: (253) 536-1759
Lakewood Water District
Spanaway Water Company
Fruitland Mutual Water

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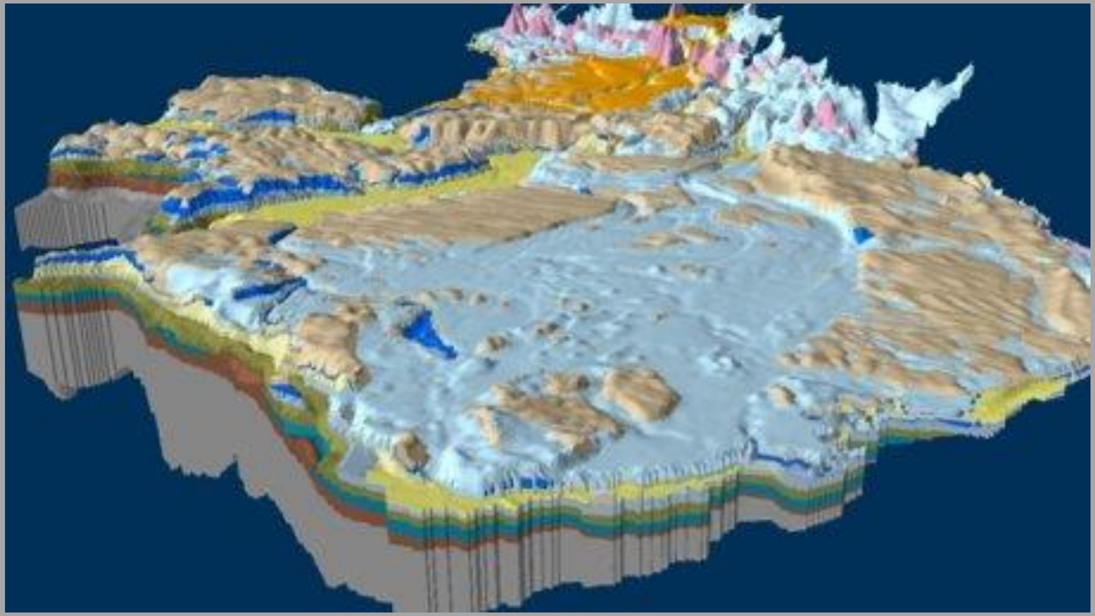
SES Project Objectives



- Characterize the groundwater-flow system
  - 3-D representation of the hydrogeologic units
  - Groundwater levels and flow directions
  - Water budget (inflows and outflows)

- Integrate the information into a numerical groundwater-flow model
- Scenarios: Simulate the potential impacts given certain conditions

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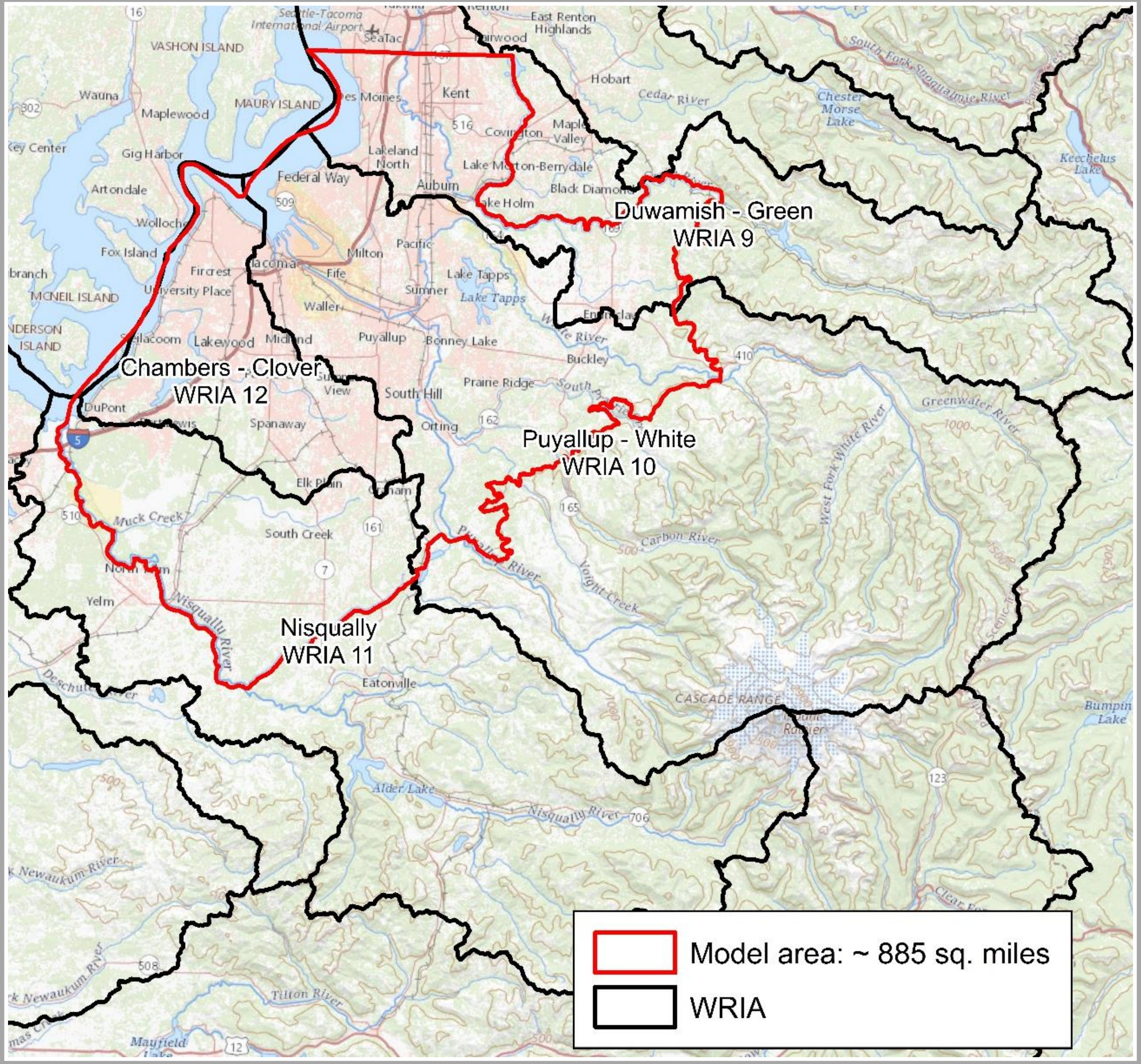
SES Study Area

- ~885 square miles
- 2010 census: 1.1 million; 89% within Urban Growth Area (UGA)
- Bounded by Puget Sound, Green River, Cascade foothills and Nisqually River



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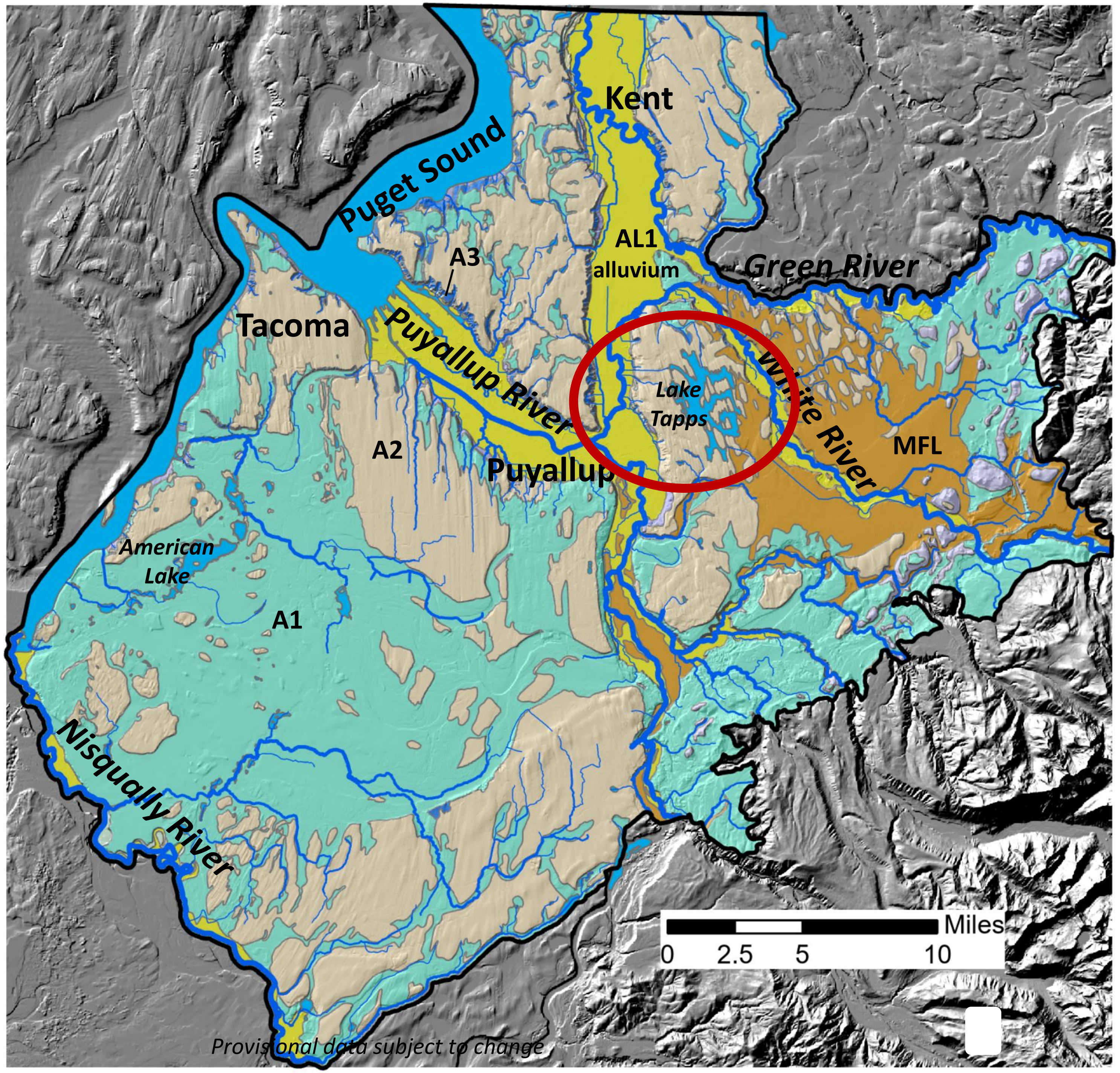
Land surface features

Hydrogeologic units

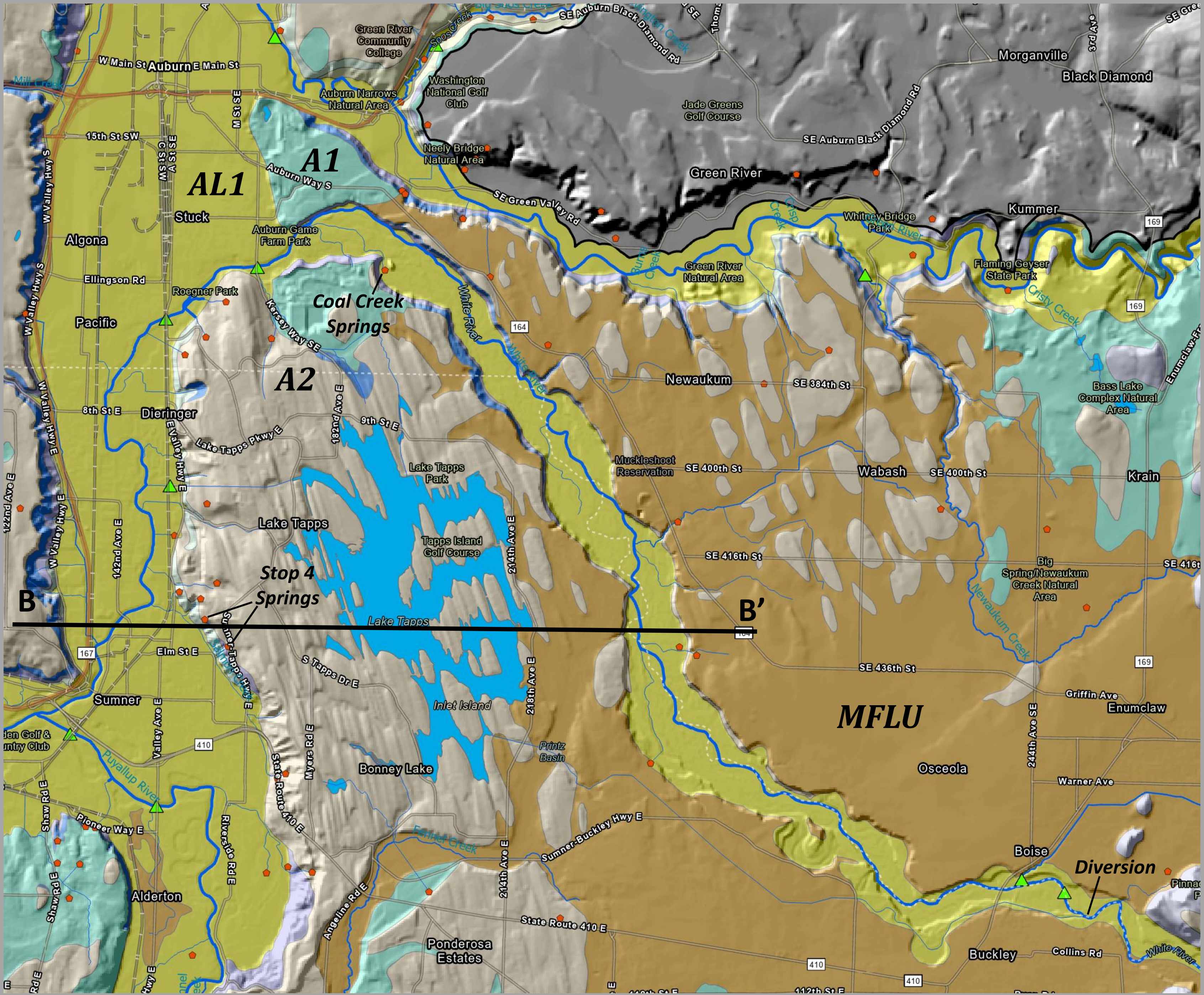
- MFL mudflow deposit
- A1 aquifer
- A2 confining unit
- A3 aquifer
- AL1 alluvium



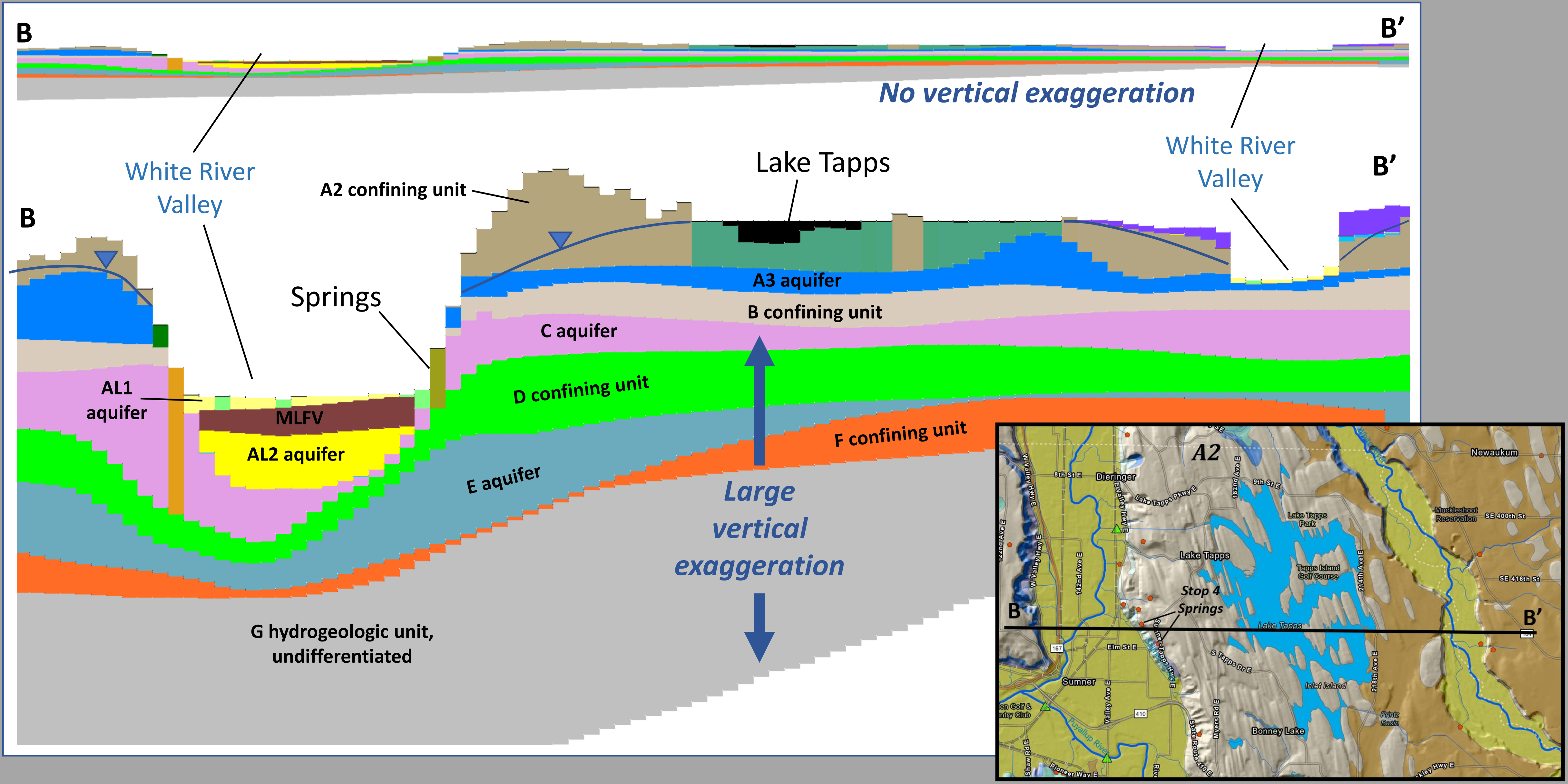
Cross-section trace through Lake Tapps and White River

Cross-section shown on next slide

Streamgage
Spring

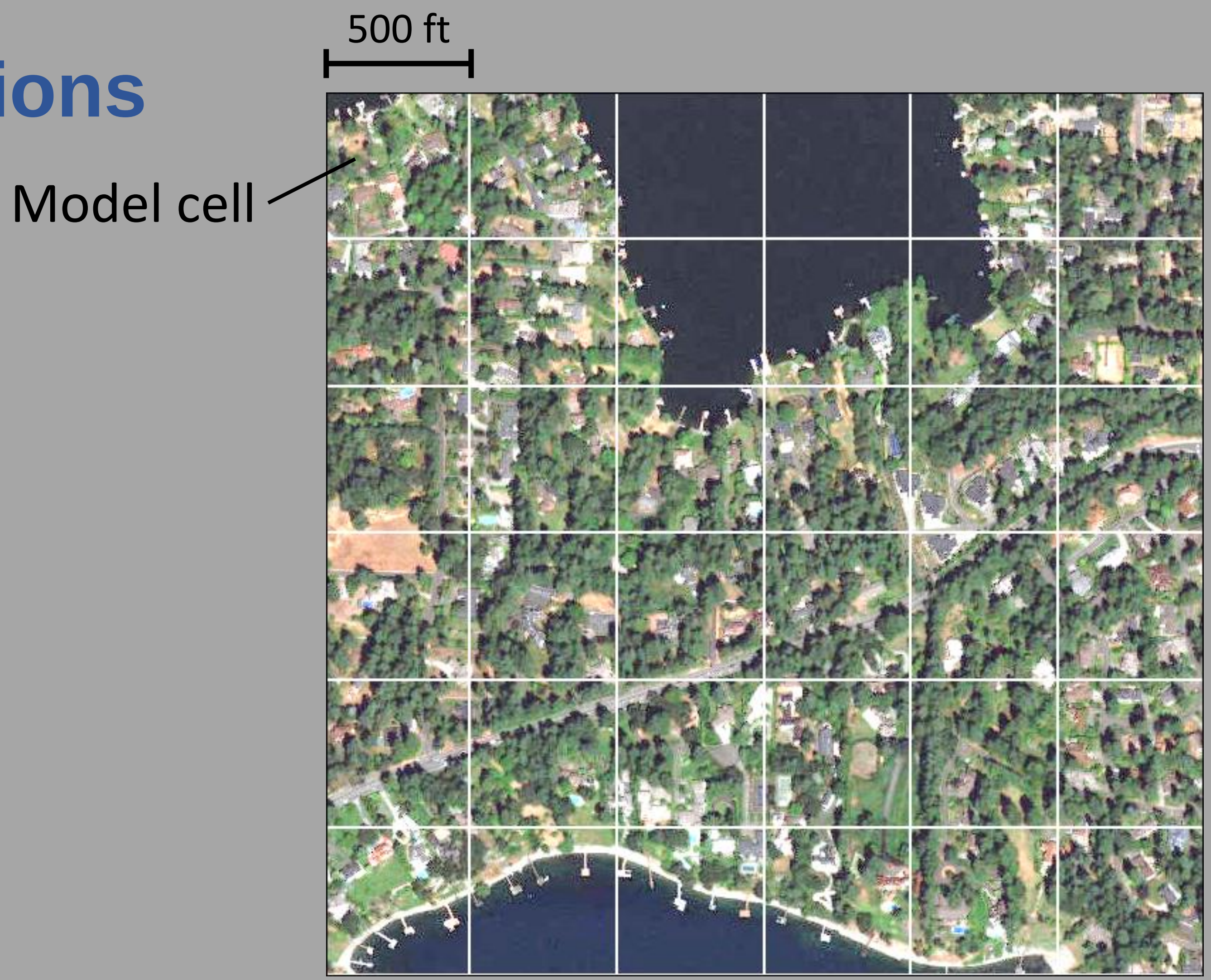


Springs associated with Lake Tapps



Model code and dimensions

- MODFLOW-NWT
- 13 model layers
- Active model cells: ~723,000
- Properties are uniform within each model cell
- Time modes
  - Steady state (average conditions)
  - Transient (January 2005 – December 2015 with monthly stress periods)



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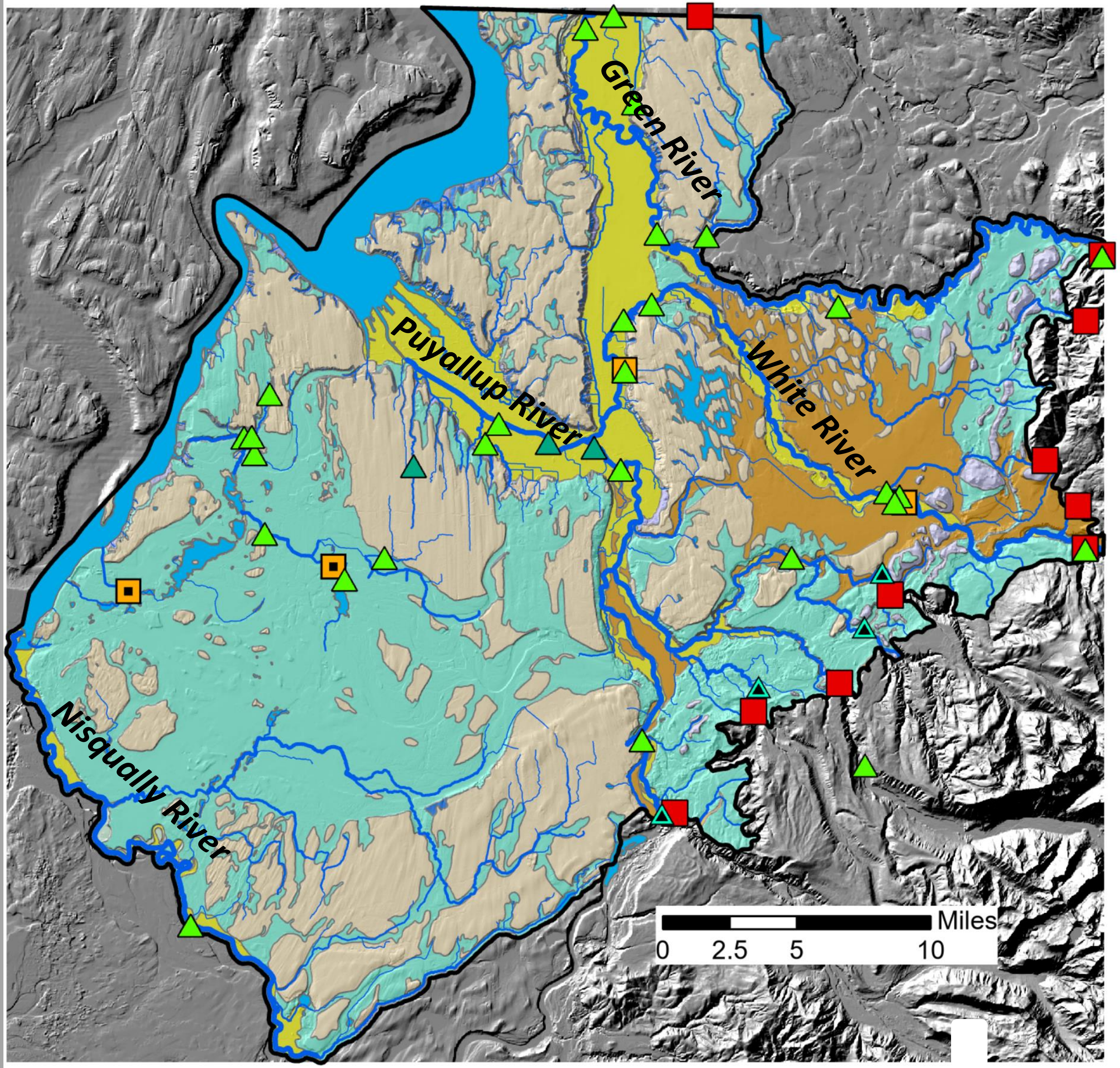
Stream features

Streamgages
- Continuous
- Seasonal
- Discrete

Stream features
- Diversion
- Specified flow

Hydrogeologic units
- MFL
- A1
- A2
- A3
- AL1



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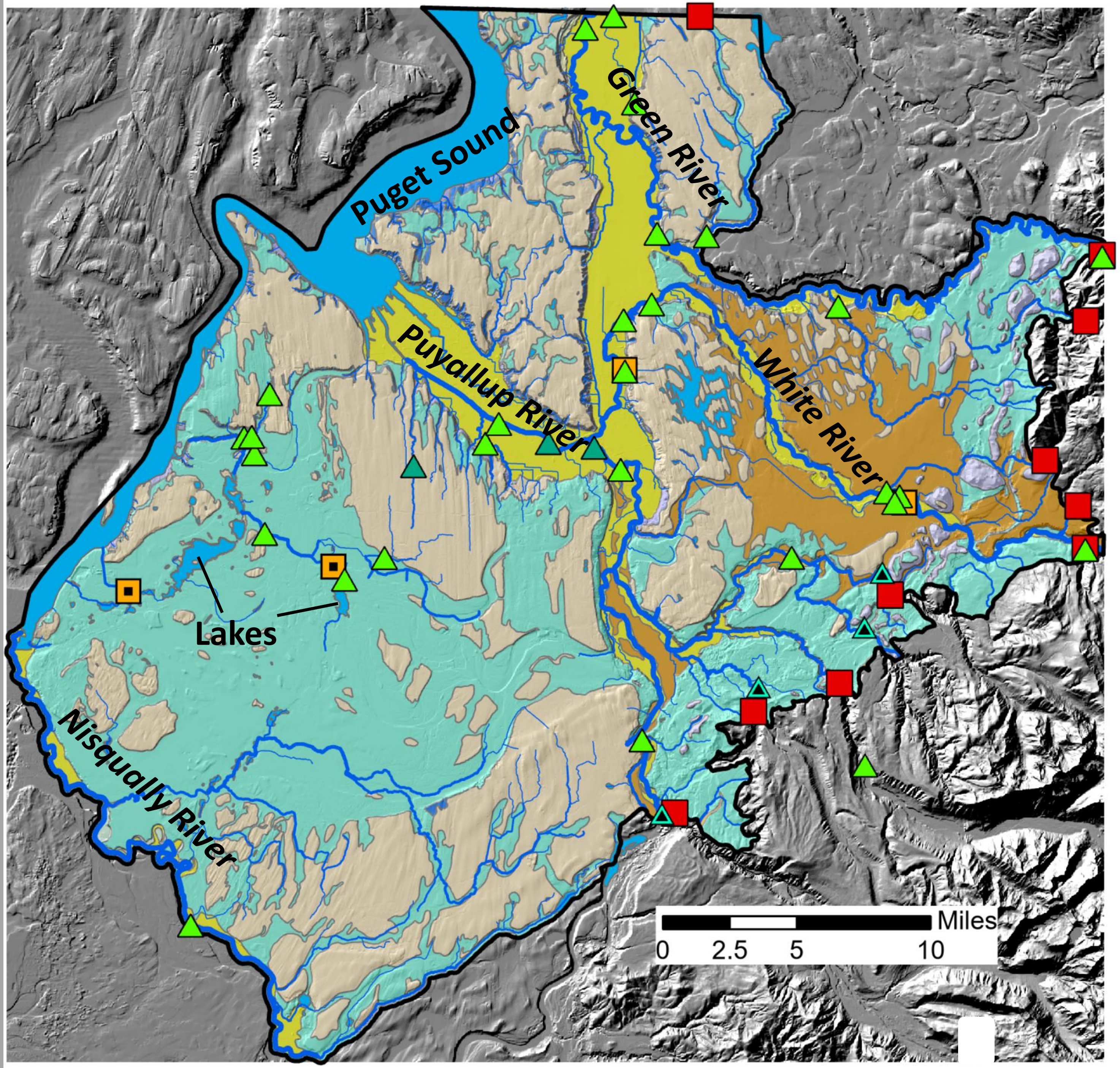
Model inflows and outflows

- Streamflow gains and losses to groundwater
- Groundwater interaction with springs, lakes, and Puget Sound
- Recharge from precipitation
- Pumping wells



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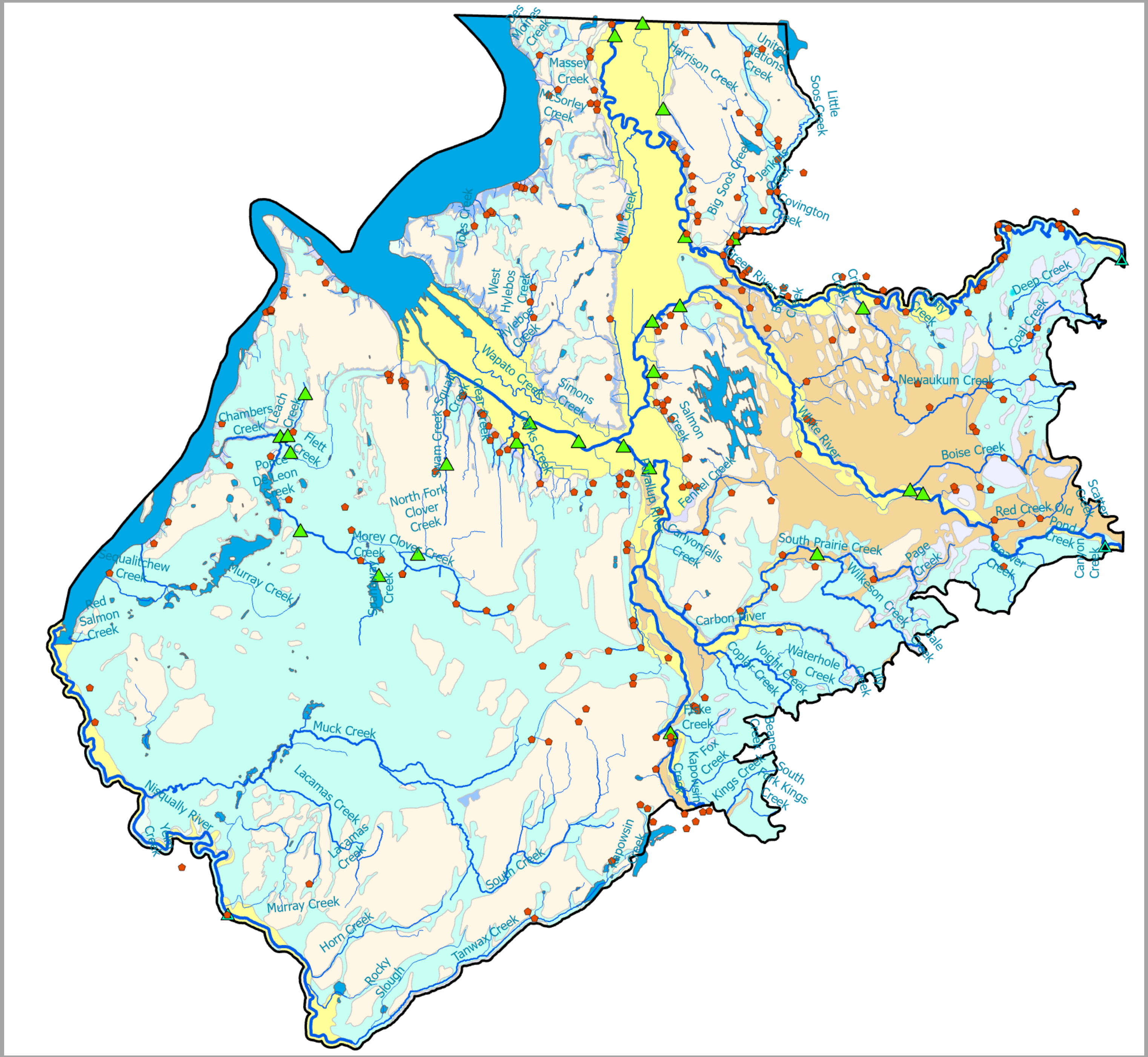
Springs

- 200 springs (red) were simulated with the SFR Package



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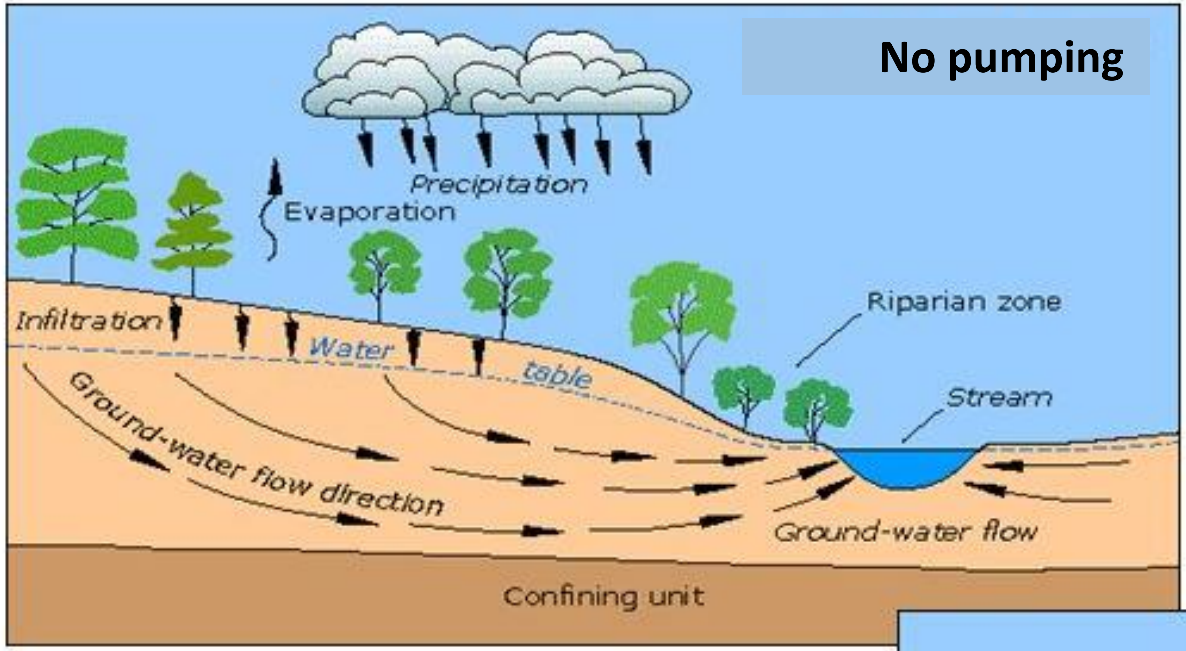
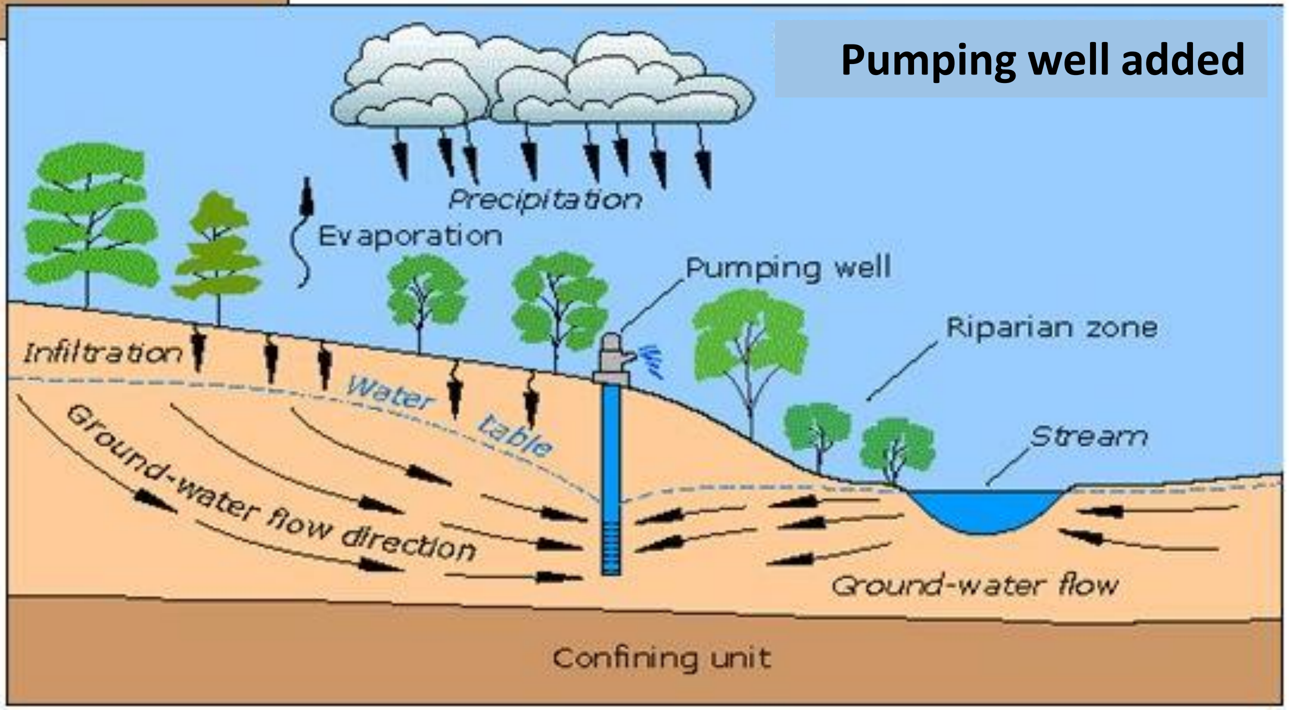


The model simulates the influence of pumping

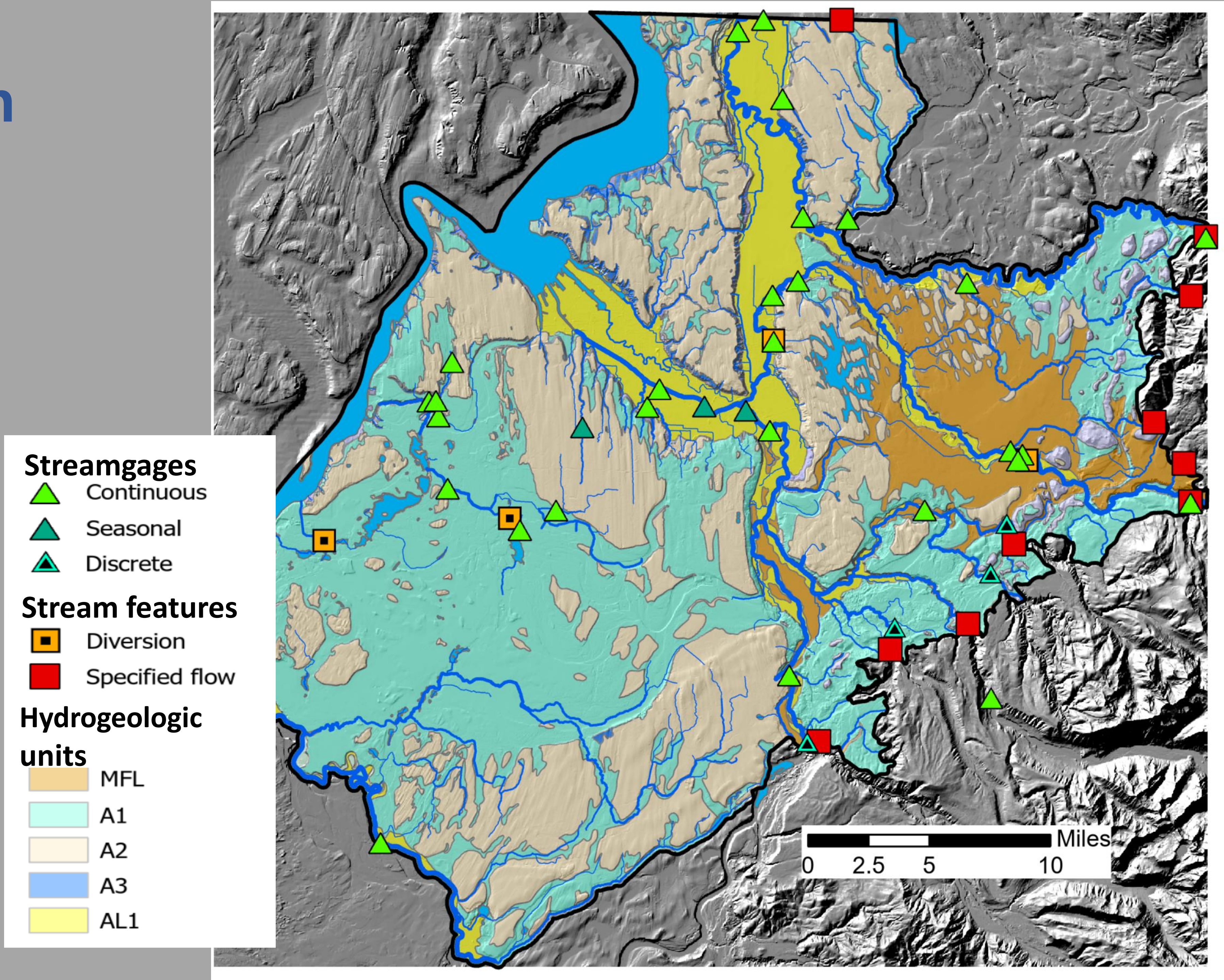


https://water.usgs.gov/edu/earthgwaquifer.html
http://slideplayer.com/slide/10608088/

(USGS)

Model calibration

- Baseflow for 25 streamgages with daily records
- Groundwater levels for ~4,000 wells (273 wells with time-series data)



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Groundwater budget

Groundwater budget component	Percentage of total inflow or outflow	
	Estimated	Simulated
Inflows		
Precipitation Recharge	98	98
Groundwater return flows	1.3	1.0
Lake Tapps seepage	0.9	1.1
Outflows		
Net discharge to streams, springs, lakes, and Puget sound	93	94
Withdrawals from wells	7.3	5.7

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Scenario 3 suite

Cyclic equilibrium with increased water use (transient model)

Four scenarios consisting of pumping increases were compared to the base model:

- 3a – base model (no change)
- 3b – All public supply wells in model
- 3c – All self-supply wells in model
- 3d – Supply wells for the Spanaway Water Company*
- 3e – Supply wells for the city of Sumner*

*Water resource mitigation pilot project for ESSB 6091

Scenario 3d - Spanaway

Cyclic equilibrium with increased water use (transient model)

Annual withdrawals by well for the Spanaway Water Company, in cubic feet					
Well ID	**City**	**Scenario 3a (base model)**	**Scenario 3d**	**Increase between 3d and 3a**	**Percent Increase**
WGpA00125	Spanaway	3,751,891	5,939,719	2,187,828	58%
WGpA00126	Spanaway	102,400	16,725,934	16,623,534	16234%
WGpA00127	Spanaway	11,629,579	15,637,006	4,007,427	34%
WGpA00128	Spanaway	12,413,484	21,168,760	8,755,276	71%
WGpA00129	Spanaway	40,926,037	63,506,281	22,580,244	55%
WGpA00130	Spanaway	0	0	0	0%
WGpA00131	Spanaway	9,677,702	21,125,203	11,447,501	118%
WGpA00132	Spanaway	22,128,483	31,753,140	9,624,657	43%
WGpA00133	Spanaway	5,590,807	10,148,809	4,558,002	82%
WGpA00134	Spanaway	29,513,824	46,562,561	17,048,737	58%
WGpA00368	Spanaway	22,959,845	31,709,583	8,749,738	38%
Total	Spanaway	158,694,052	264,276,996	105,582,944	67%

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Scenario 3e - Sumner

Cyclic equilibrium with increased water use (transient model)

Annual withdrawals by well for the city of Sumner, in cubic feet					
Well ID	**City**	**Scenario 3a (base model)**	**Scenario 3e**	**Increase between 3e and 3a**	**Percent Increase**
WGpA00185	Sumner	12,961,755	16,932,478	3,970,723	31%
WGpA00186	Sumner	61,531,089	80,380,616	18,849,527	31%
WGpA00187	Sumner	0	0	0	0%
WGpA00188	Sumner	391,485	2,904,002	2,512,517	642%
WGpA00189	Sumner	337,518	23,613,412	23,275,894	6896%
WGpA00190	Sumner	1,369,294	4,810,591	3,441,297	251%
WGpA00369	Sumner	0	27,214,200	27,214,200	NA
Total	Sumner	76,591,141	155,855,299	79,264,158	103%

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Scenario 3 – Spanaway and Sumner

Cyclic equilibrium with increased water use (transient model)

Description	Units	Scenario 3b[2]	Scenario 3c[3]	Scenario 3d[4] Spanaway	Scenario 3e[5] Sumner
Percent change in average consumptive water use	Percent	12.99	0.21	4.09	2.93
Percent change in average simulated baseflow for all streams and springs[1]	Percent	-0.48	-0.02	-0.17	-0.13
Change in average consumptive water use	ft^3/s	10.3	0.2	3.3	2.3
Change in average simulated baseflow for all streams and springs[1]	ft^3/s	-6.8	-0.3	-2.4	-1.9
Change in baseflow as percentage of the change in consumptive use	Percent	-65.3	NA[6]	-73.8	-80.8

[2] Scenario 3b: 15 percent increase in groundwater use for Group A and Group B public-supply wells.
[3] Scenario 3c: 15 percent increase in groundwater use self-supply wells.
[4] Scenario 3d: increase in groundwater use to simulate the Spanaway pilot project.
[5] Scenario 3e: increase in groundwater use to simulate the Sumner pilot project.
[6] Model error resulted in a change in baseflow that is larger than the change in consumptive water use.

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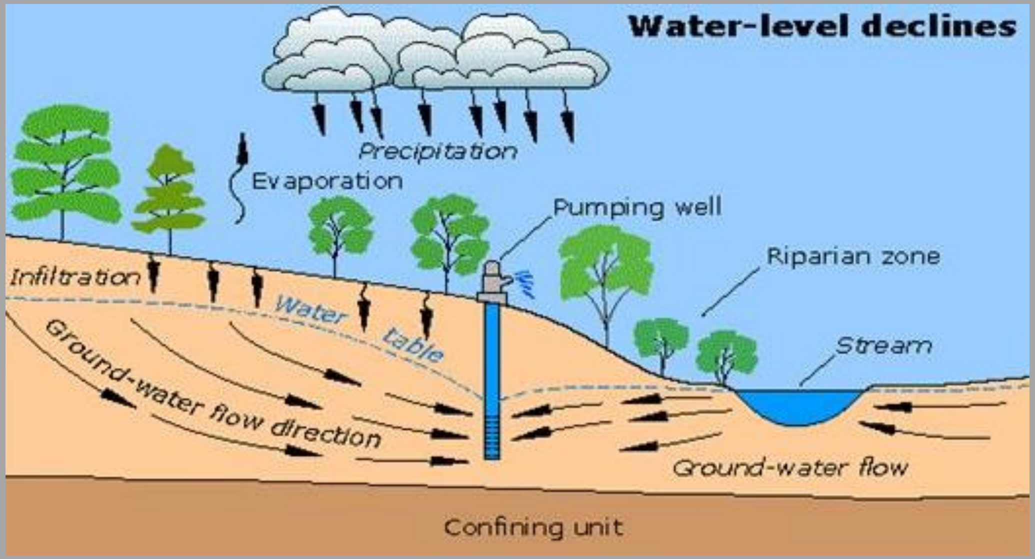
Key points

- The model was calibrated to groundwater levels and stream baseflow
- The model simulates the effects of pumping and drought on stream baseflow and groundwater levels
- Although a model may provide the best answers available, we also accept its limitations



Questions

Additional slides for reference:

Scenario 1 *(a, b, & c)*

Change in baseflow for long-term equilibrium (steady-state simulation)

Description	Units	Scenario 1a	Scenario 1b	Scenario 1c
Change in recharge	Percent	-15	-20	-25
Change in average simulated baseflow for all streams and springs[1]	Percent	-17	-23	-28
Change in recharge	ft^3/s	-269	-358	-448
Change in average simulated baseflow for all streams and springs[1]	ft^3/s	-208	-281	-353
Change in baseflow as a percentage of the change in recharge	Percent	-77	-79	-79

[1]The change in total baseflow is equivalent to the change in model-area baseflow for this scenarios.

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Scenario 1d

Variable conditions with three years of summer drought for 2009-2011 (transient simulation)

Description	Units	2009	2010	2011	2012	2013	2014	2015
Change in recharge for May-August	Percent	-99	-99	-99	0	0	0	0
Change in simulated baseflow at end of August for all streams and springs[1]	Percent	-2	-13	-5	-2	-1	-0.7	-0.6
Change in baseflow as a percentage of the change in recharge	Percent	-11	-36	-17	NA	NA	NA	NA

[1]Table shows model-area baseflow consisting of baseflow gain simulated within the active model area only, excluding flows entering from outside of the active model area.

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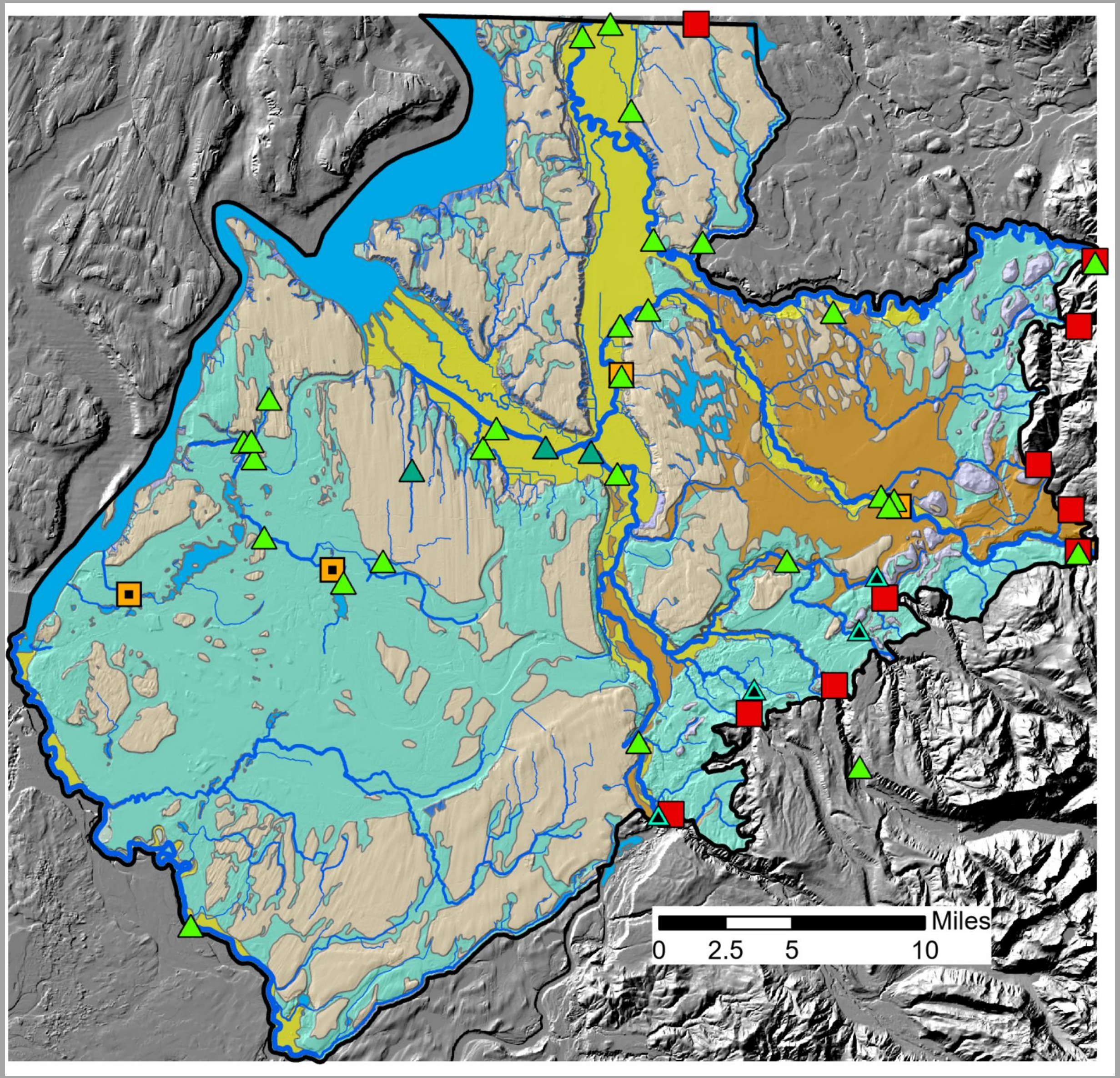
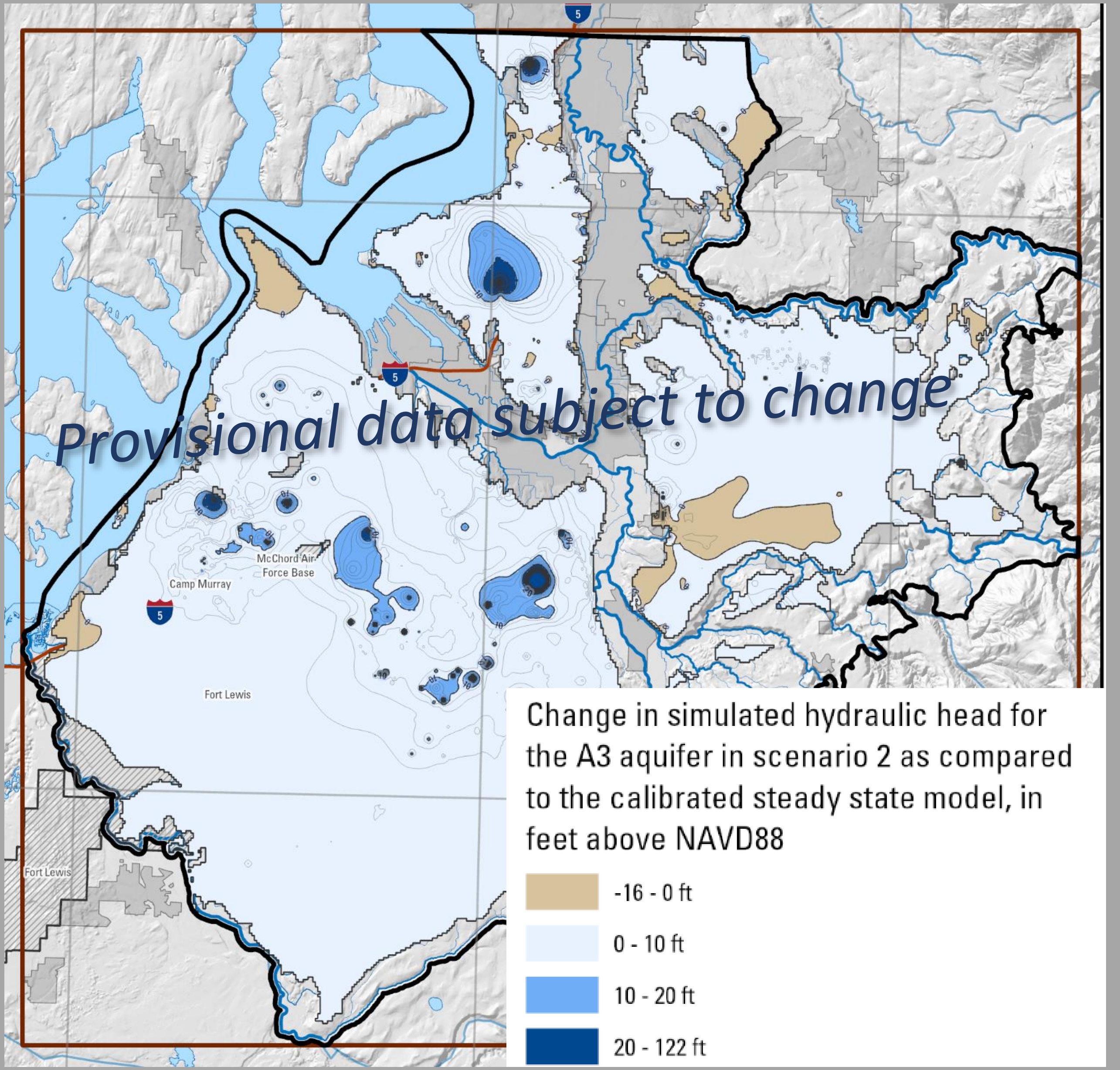
Scenario 2

No groundwater use compared with average groundwater use (steady state)





Model limitations

- Error and uncertainty result because of approximations, assumptions and simplifications
- Uncertainty of input and calibration data (e.g., stratigraphic framework, recharge, water use, and baseflow)
- Time scale may not represent full range of actual hydrologic variability
- For simulating local-scale processes, a regional model has limitations related to
  - Grid resolution
  - Calibration detail at local scales